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New herpetofaunal records from Gunung Mulu National Park and its surrounding areas in Borneo

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Abstract

Gunung Mulu National Park (GMNP) in northwestern Borneo is marked by high species diversity and diverse environments. We present one new amphibian and ten new reptile records from GMNP and its surrounding area. In the records, *Asthenodipsas jamilinaisi* and *Garthius chaseni* were newly recorded in the Sarawak State. We also present the first record of *Cyrtodactylus muluensis* from outside of GMNP and the second record of *Opisthotropis typica* from the park. Combined with previous information, a total of 108 amphibians and 104 reptiles are known from GMNP, and their preferred habitat types are diverse. Furthermore, observed male-male combat of *Dopasia buettikoferi* is the first detailed description of the genus. Two color morphs of *D. buettikoferi* had an identical ND2 haplotype and appeared to be the same species. The present study provides new information about Bornean amphibians and reptiles, and also emphasizes the importance of continuous monitoring.

Key Words

Amphibia, *Dopasia*, inventory, male-male combat, Miri, new locality, Reptilia, Sarawak, species diversity

Introduction

Gunung Mulu National Park (GMNP) in northwestern Borneo, which was registered as a World Heritage Site in 2000, is famous for its remarkable species diversity and various abiotic and biotic environments. A variety of geological types and a wide altitude range within GMNP (from the headquarter area at < 50 m above sea level (a.s.l.) to the peak of Mt. Mulu at 2,376 m a.s.l.) allow the formation of the various types of vegetation, such as mossy forests, lower montane forests, lowland mixed dipterocarp forests, upper montane limestone forests, lower montane limestone forests, lowland limestone forests, riverine forest, kerangas forests, and peat swamp forests (Hazebroek and Morshidi 2001). It supports more than 3,500 species of plants, 8,000 species of fungi, and 20,000 species of animals (Hazebroek and Morshidi 2001).

Species recorded from GMNP include 107 amphibian and 93 reptile species (Mori 1993; Das et al. 2017; Inger et al. 2017; Davis et al. 2019; Matsui et al. 2020; Haas et al. 2021), of which 10 frog species and one gecko species are endemic to this area (Inger et al. 2017; Davis et al. 2019).

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Although more than 40 years of herpetological research has been conducted in GMNP, several undescribed and unrecorded species in this area have been found, even in recent years (Dehling 2011; Dehling and Matsui 2013; Eto et al. 2015, 2016; Davis et al. 2019; Matsui et al. 2020).

The earliest study of herpetofauna in GMNP was conducted during an expedition by the Royal Geographical Society and the Sarawak Government from 1977 to 1978, which reported 50 species of reptiles (Dring and Kiew 1982) and described several new species of amphibians (Dring 1983a, b, 1987; Kiew 1984; Dubois 1987). Since then, many surveys, the majority of which were taxonomic studies, have been conducted by research teams. One gecko species and 21 frog species have been described in total so far from GMNP, of which 6 were described over the past decade (Dehling 2011; Dehling and Matsui 2013; Eto et al. 2015, 2016; Davis et al. 2019; Matsui et al. 2020). Using museum specimens and literature reports, Das et al. (2008) reported 91 reptile species from GMNP. More recently, Das et al. (2017) provided a comprehensive species checklist of amphibians and reptiles in GMNP. However, the lack of voucher information and, for many species, photographs made it difficult to investigate the primary sources of the records. Constant surveys and renewal of inventory are crucial for the recognition of overlooked, newly recorded, newly-described, and taxonomically-revised species. Thus, it is important to maintain up-to-date records of known reptile and amphibian diversity in this area.

In 2018 and 2019, we conducted surveys of the herpetofauna in GMNP and adjacent areas and found some remarkable species. Here, we present one amphibian and 10 newly recorded reptile species from the Mulu area, of which two are newly recorded in the Sarawak State. We also provide some noteworthy natural history records of previously known species.

Methods

Field visual encounter surveys were conducted on three occasions in GMNP which is located in northeastern Sarawak, Malaysian Borneo (Fig. 1). Field surveys were carried out on 3–17 August 2018 by R.F., I.F., T.K., Y.K., and M.Y.H.; 11–15 December 2018 by I.F., M.Y.H., and A.N.; and 6–16 August 2019 by I.F., Y.K., and M.Y.H. Our survey areas included the headquarter area (HQ, Paku Valley Loop, and Moonmilk Trail; Fig. 2A), the Summit Trail of Mt. Mulu (Camps 1–4 and the summit; Fig. 2B, C), and the Pinnacle Trail of Mt. Api (Camp 5; Fig. 2D) in GMNP, and Bukit Pala, outside the national park. This site is a small limestone hill which is located 1–2 km from the main karst body in GMNP and is adjacent to a village, a road, and a river (Dring 1983b). The surveys were conducted day and night. Identification of species was done by *in-situ* observations and photographs, and for some species, such as those newly recorded from GMNP and required further taxonomic investigation, the minimum necessary numbers of individuals were collected. The collected specimens were deposited in the Graduate School of Human and Environmental Studies, Kyoto University (KUHE) and the Sarawak Research Collection, Sarawak Forest Department (SRC) with permission from the authorities.

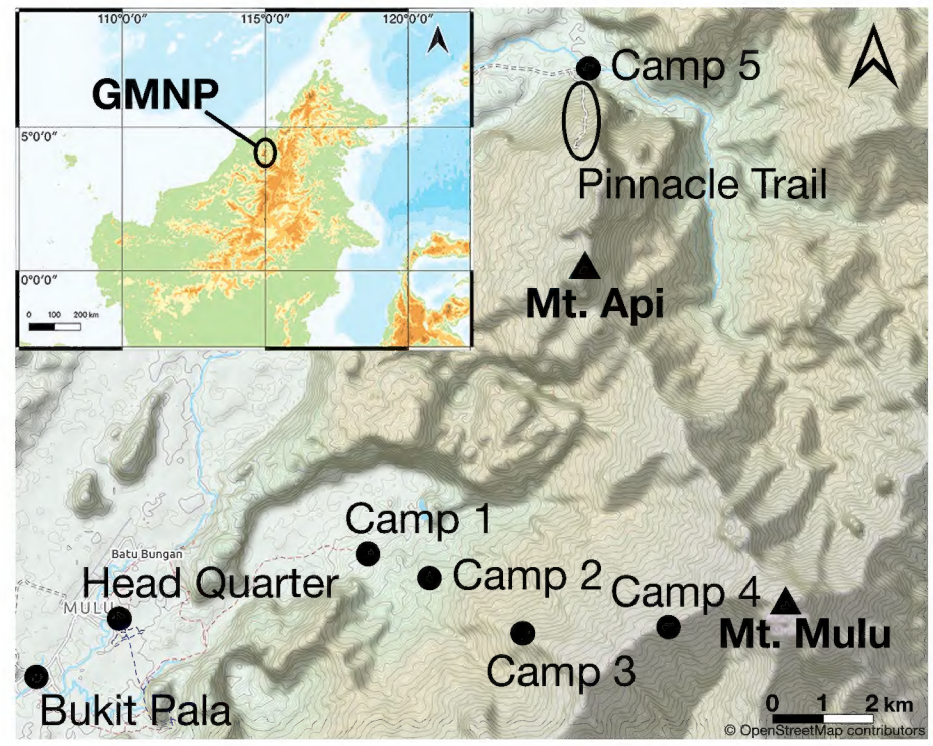

Figure 1. Map of Gunung Mulu National Park indicating the surveyed locations. This map is based on the GSI Maps published by the Geospatial Information Authority of Japan and OpenStreetMap.

Results

Two snake species (*Asthenodipsas jamilinaisi* and *Garthius chaseni*) were newly recorded from Sarawak. One amphibian (*Ingerophrynus quadriporcatus*) and eight reptile species (*Dopasia buettikoferi*, *Calamaria lumbricoidea*, *Hebius flavifrons*, *Lycodon albofuscus*, *Oligodon signatus*, *Oreocalamus hanitschi*, *Bungarus fasciatus*, and *Notochelys platynota*) were newly recorded from the Mulu area. *Opisthotropis typica*, found at Mt. Mulu, was the second record of this species from GMNP. *Cyrtodactylus muluensis*, found from Bukit Pala, was the first record from outside the park.

Ingerophrynus quadriporcatus (Boulenger, 1887)

Fig. 3A

Specimen examined. One specimen (SRC 00583) was found in Paku Valley Loop near HQ (4°2.89'N, 114°49.46'E, ca. 40 m a.s.l.) in August.

Ecological notes. The individual was sitting on the grass, approximately 15 cm above the ground at 0119 h.

Distribution in Borneo. This species has been broadly recorded from the coastal area of Borneo (Grafe et al. 2010; Inger et al. 2017).

Figure 2. Variations in the vegetation of the survey area. **A.** Riverine forest and the boardwalk near HQ; **B.** Lowland mixed dipterocarp forest between Camps 2 and 3; **C.** Mossy forest between Camps 3 and 4; **D.** lowland limestone forest of the Pinnacle Trail.

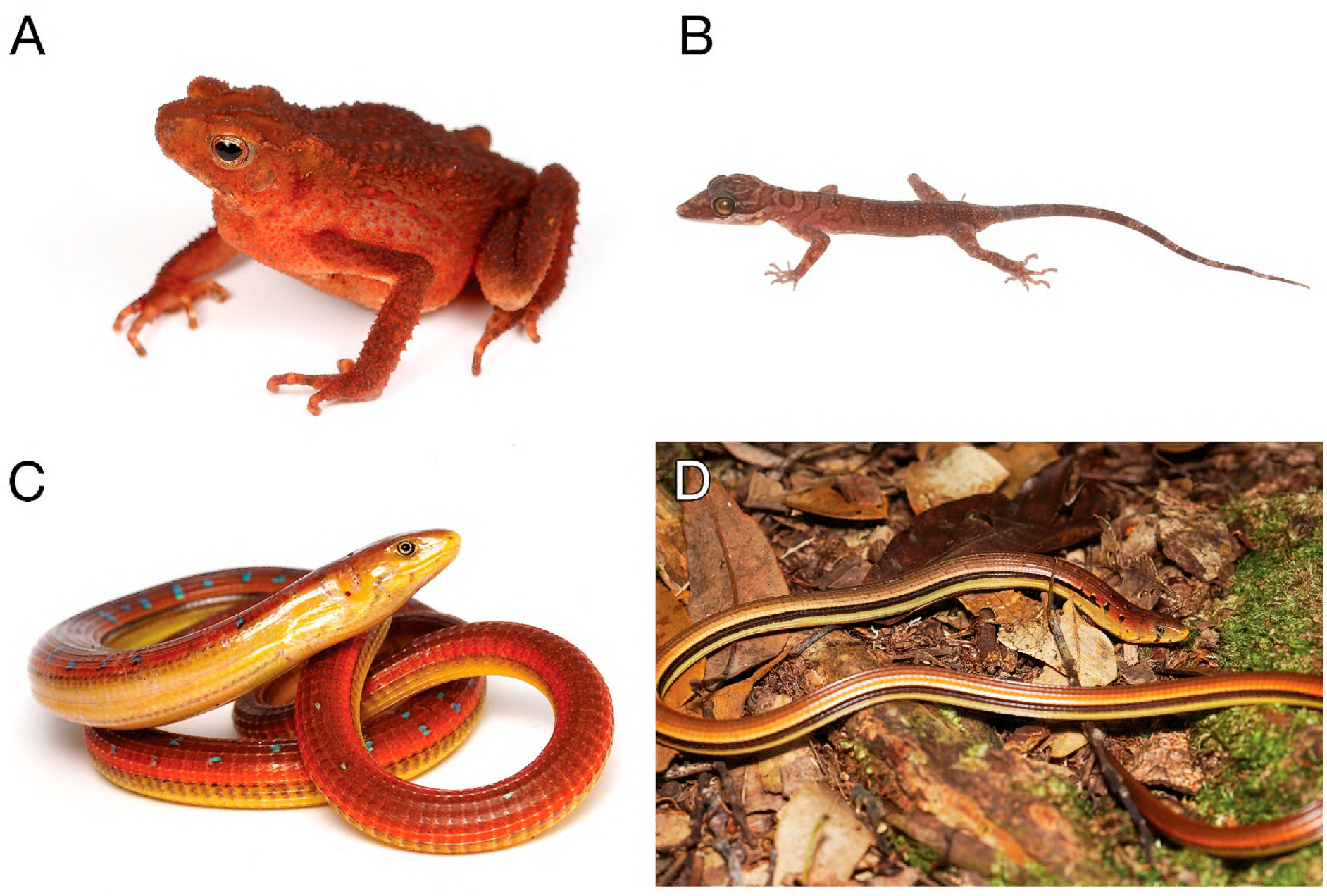

Figure 3. Newly recorded amphibian and lizards from the Mulu area. **A.** *Ingerophrynus quadriporcatus*; **B.** *Cyrtodactylus muluensis* (SRC 00591); **C, D.** Male (C; SRC00627) and female (**D.**) specimens of *Dopasia buettikoferi*.

Cyrtodactylus muluensis Davis, Bauer, Jackman, Nashriq & Das, 2019

Fig. 3B

Specimens examined. Two specimens were found on a karst outcrop near Camp 1 (4°2.90'N, 114°51.30'E, ca. 300 m a.s.l.; SRC 00651) and Bukit Pala (4°1.93'N, 114°47.96'E, ca. 50 m a.s.l.; SRC 00591) in August. This species was also observed on the Moonmilk Trail near HQ in August.

Ecological notes. The individual near Camp 1 was found on limestone cliffs in the karst forest at 0220 h. The individual from Bukit Pala was climbing a tree in the karst forest at ca. 2300–2400 h. The individual from Moonmilk Trail was found on limestone cliffs in the karst forest at 2118 h.

Distribution in Borneo. This species has been recorded from the Clearwater Cave, Long Cave, and Lang Cave within GMNP (Davis et al. 2019). Our observation from Bukit Pala is the first record from outside GMNP.

Dopasia buettikoferi (Lidth de Jeude, 1905)

Fig. 3C, D

Specimens examined. Two males (SRC 00626 and 00627) were found at the same time from the Summit Trail between Camps 2 and 3 (4°2.53'N, 114°52.70'E, ca. 890 m a.s.l.) in August. One female (SRC 00632) was also found from the same area (4°2.42'N, 114°52.83'E, ca. 990 m a.s.l.) during the same survey.

Ecological notes. The males were found on the dipterocarp forest floor at 1525 h. The larger male [147 mm in snout-vent length (SVL) and 447 mm in tail length (TL)] violently bit the dorsal part of the smaller male's nape (145 mm in SVL and 432 mm in TL) and wound itself around the smaller male, while the smaller twisted its body to escape. This behavior was considered a male-male agonistic interaction. The smaller male had scars resulting from the biting on its lower jaw, nape, and anterior part of the body, and the ventral side of the tail (Suppl. material 1). The larger male also had some scars on the head. The female specimen was found on the trail of dipterocarp forest at 1256 h in a sunny location.

Distribution in Borneo. This species has been recorded from 11 localities across western and northern Borneo (ca. 230–1300 m a.s.l.) (Jablonski et al. 2020).

Remarks. The first and second specimens had different colors from the third specimen. Colorations of the first and second specimens were similar to the first individual of Jablonski et al. (2020): the dorsum was reddish-brown interspaced by several blue dots and the ventral side was uniformly yellow. On the other hand, the third individual was similar to those reported by Jablonski et al. (2020): it consists of dark-colored subocular stripes together with other stripes on the head bordered by light-colored margins. Although Jablonski et al. (2020) hypothesized that the former type would be a cryptic species, the two morphotypes in our specimens had an identical haplotype for the mitochondrial ND2 gene (1098 bp; accession numbers LC600804 and LC600805 for SRC 00626 and 00632, respectively), suggesting that they are the same species.

Asthenodipsas jamilinaisi Quah, Grismer, Lim, Anuar & Imbun, 2019

Fig. 4A

Specimens examined. One specimen (SRC 00866) was observed on the Summit Trail between Camps 2 and 3 (4°2.28'N, 114°53.16'E, ca. 1,280 m a.s.l.) in December.

Ecological notes. The specimen was found on a shrub, approximately 60 cm above the ground, at 2023 h.

Distribution in Borneo. This species has been recorded from the highlands of Sabah (Mt. Trusmadi and Mt. Kinabalu) (Quah et al. 2019). Our observation is the first record from Sarawak and also the southernmost record to date.

Calamaria lumbricoidea Boie, 1827

Fig. 4B

Specimen examined. One specimen (SRC 00630) was observed at Camp 1 (4°3.01'N, 114°51.47'E, ca. 210 m a.s.l.) in August.

Ecological notes. This specimen was found on the bare ground at 1040 h.

Distribution in Borneo. This species has been broadly recorded from Sarawak, Sabah, and eastern and southeastern Kalimantan (Stuebing et al. 2014).

Hebius flavifrons (Boulenger, 1887)

Fig. 4C

Specimens examined. Two individuals were observed near Camp 2 (4°2.51'N, 114°52.28'E, ca. 500 m a.s.l.) in August.

Ecological notes. The two specimens were lying on shrub leaves (ca. 30 cm above the ground and ca. 50 cm from a stream) at 2358 and 0128 h, respectively.

Distribution in Borneo. This species is widespread in Borneo, from sea level to 700 m a.s.l. (Stuebing et al. 2014).

Lycodon albofuscus (Dumeril, Bibron & Dumeril, 1854)

Fig. 4D

Specimen examined. One adult (SRC 00654) was found on the Moonmilk Trail (4°3.03'N, 114°49.40'E, ca. 70 m a.s.l.) in August.

Ecological notes. The specimen was lying on the riverine forest floor at 2330 h.

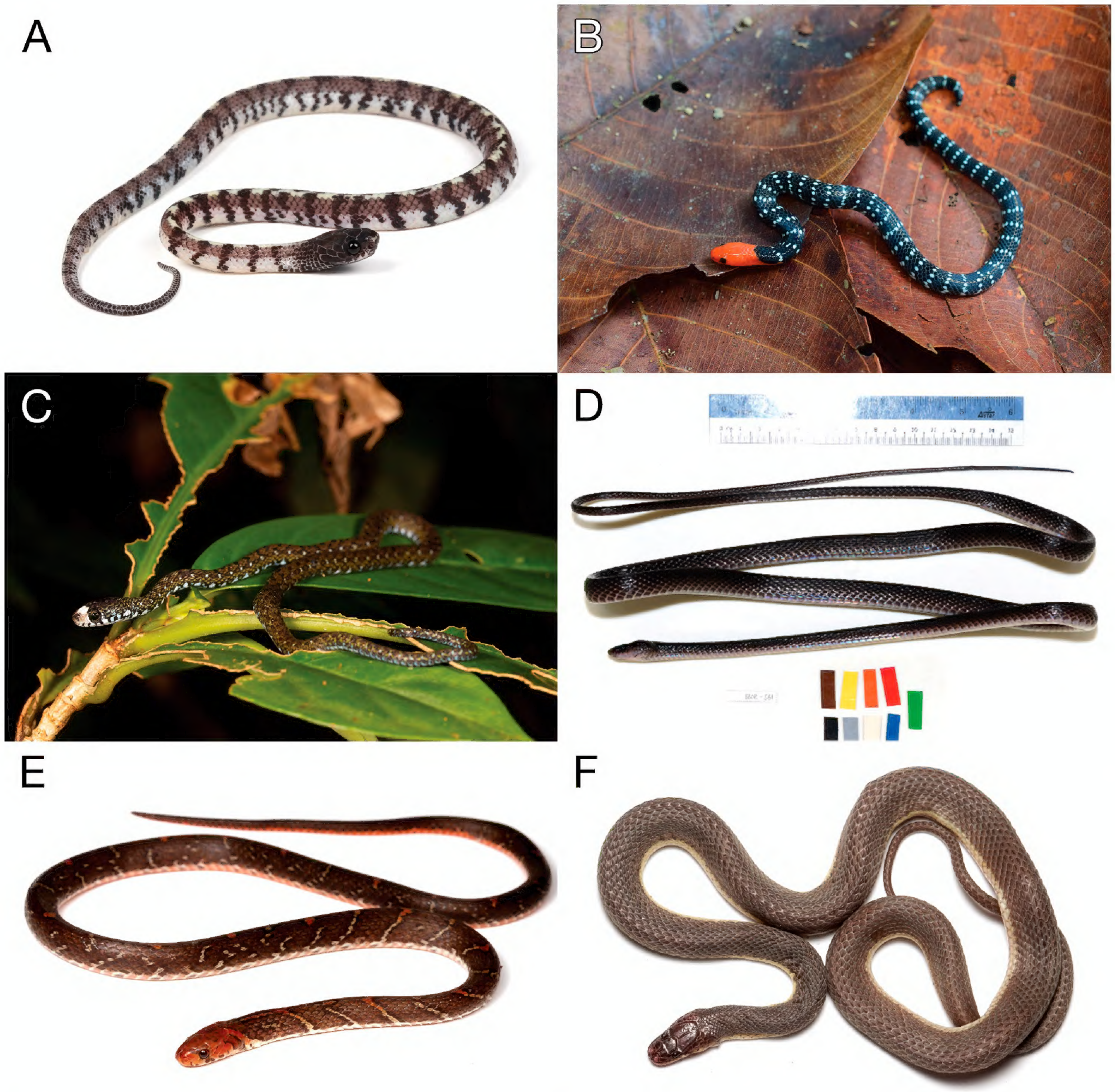

Figure 4. Snakes with noteworthy distributional records from the Mulu area. **A.** *Asthenodipsas jamilinaisi*; **B.** *Calamaria lumbricoidea*; **C.** *Hebius flavifrons*, lying on shrub leaves near Camp 2; **D.** *Lycodon albofuscus*; **E.** *Oligodon signatus*; **F.** *Opisthotropis typica*.

Distribution in Borneo. This species is widespread in lowland areas of Borneo (< 500 m a.s.l.) (Stuebing et al. 2014).

Oligodon signatus (Günther, 1864)

Fig. 4E

Specimen examined. One specimen (SRC 00594) was collected from Bukit Pala (4°1.92'N, 114°47.96'E, ca. 50 m a.s.l.) in August.

Ecological notes. The specimen was found crawling on the ground at 2339 h.

Distribution in Borneo. This species has been recorded from several sites of Sarawak and at one location of the Sabah State, where their distribution ranges from 190 to 350 m a.s.l. (Stuebing et al. 2014).

Opisthotropis typica (Mocquard, 1890)

Fig. 4F

Specimen examined. One specimen (SRC 00660) was found near Camp 2 (4°2.52'N, 114°52.30'E, ca. 520 m a.s.l.) in August.

Ecological notes. The specimen was slowly swimming in a pool area of a stream (ca. 40 cm depth) at 2435 h.

Distribution in Borneo. This species has been recorded in lowland areas, from 50 to 900 m a.s.l., of Sarawak, Brunei, eastern and western Sabah, and Central

Kalimantan (Stuebing and Inger 1998; Stuebing et al. 2014). Our observation is the second record from GMNP.

Remarks. *Opisthotropis typica* was recorded from GMNP by Mori (1993), but not listed on the checklist of Das et al. (2017).

Oreocalamus hanitschi Boulenger, 1899

Fig. 5A

Specimen examined. One female (KUHE 62435) was found on the Summit Trail between Camps 3 and 4 (4°2.08'N, 114°53.88'E, ca. 1690 m a.s.l.) in August.

Ecological notes. The specimen was observed on the trail at 0935 h.

Distribution in Borneo. This species has been recorded from the highlands of Sabah, northern Sarawak (Kelabit Plateau), and upper east and central Kalimantan, where their distribution ranges from 1,120 to 1,800 m a.s.l. (Stuebing et al. 2014).

Bungarus fasciatus (Schneider, 1801)

Fig. 5B

Specimens examined. Two specimens (SRC 00588 and 00595) were collected from Jalan Mulu Utama (4°2.11'N, 114°48.13'E and 4°2.38'N, 114°48.32'E, respectively), at approximately 20 m a.s.l., in August.

Ecological notes. The first specimen was found dead beside the road at 2228 h. The second specimen was found slowly crawling beside the road at 0227 h.

Distribution in Borneo. This species has been recorded from the lowlands of Sarawak, Brunei, Sabah, and Kalimantan (Stuebing et al. 2014).

Remarks. Although *B. fasciatus* was not listed on the checklist of Das et al. (2017), unconfirmed records were verbally described by local people (Das et al. 2008).

Garthius chaseni (Smith, 1931)

Fig. 5C

Specimen examined. An adult male (SRC 00661) was observed in August from the Pinnacle Trail, on the northern slope of Mt. Api (4°7.60'N, 114°53.62'E, ca. 910 m a.s.l.).

Ecological notes. The specimen was found in the karst forest at 2325 h.

Distribution in Borneo. This species is only known to inhabit the mountain forests of Mt. Kinabalu (from 915 to 1,430 m a.s.l.) and the Crocker Range (ca. 1,200 m a.s.l.) in Sabah (Stuebing et al. 2014). Our observation is the first record from Sarawak and is also the southernmost record.

Figure 5. Newly recorded snakes and turtle from the Mulu area. **A.** *Oreocalamus hanitschi*; **B.** *Bungarus fasciatus*; **C.** *Garthius chaseni* found on the Pinnacle Trail; **D.** *Notochelys platynota* found on the bottom of a small river near the HQ.

Notochelys platynota (Gray, 1834)

Fig. 5D

Specimen examined. An adult observed in August near HQ (4°1.45'N, 114°49.19'E, ca. 50 m a.s.l.).

Ecological notes. The specimen was found on the bottom of a small river at 2258 h.

Distribution in Borneo. This species has been recorded from several places in the north of Borneo, especially from the Baram River system (Iverson 1992), where GMNP is located.

Discussion

Our new records update the total numbers of amphibians and reptiles of GMNP and the surrounding areas to 108 and 104 species, respectively. Many of them are exclusive to particular environments, such as *O. hanitschi* in the lower mountain forest, *D. buettikoferi* in mixed dipterocarp forest, *Glyphoglossus flavus* in kerangas forest, and *C. muluensis* in karst forest (Stuebing et al. 2014; Inger et al. 2017; Davis et al. 2019; Jablonski et al. 2020). According to Dehling and Dehling (2021), different lowland forest types of GMNP harbor distinct frog communities. A variety of geological soil types and wide altitude ranges allow GMNP to harbor large numbers of amphibian and reptile species.

We found that the distributions of some highland species are wider than previously reported. Two snake species, *A. jamilinaisi* and *G. chaseni*, which were thought to be endemic to Mt. Trusmadi and Mt. Kinabalu (Quah et al. 2019), and Mt. Kinabalu and the Crocker Range (Stuebing et al. 2014), respectively, were recorded in Sarawak for the first time in this study. This is not surprising because some other highland species in GMNP also have large distributions in the highlands of northern Borneo [e.g., *Meristogenys kinabaluensis* (Inger et al. 2017) and *Rhabdophis murudensis* (Stuebing et al. 2014)]. Furthermore, *Trimeresurus sabahi sabahi*, which is endemic to the highlands of north Sarawak and Sabah (Stuebing et al. 2014), was observed by some national park staff on the Summit Trail of Mt. Mulu. Most parts of the highlands in Borneo are still difficult to access, and thus field surveys are insufficient yet.

The species diversity of amphibians and reptiles in the areas adjacent to GMNP is also remarkable in the context of herpetofaunal diversity of the Mulu area. Two newly recorded snakes were observed outside the park, an area where researchers may have paid little attention. In Bukit Pala, endemic karst-dwelling species, *Pelophryne api* and *C. muluensis* were observed. There are other such small limestone hills around GMNP, however, most of them have not yet been surveyed. These patchy habitats may be important for endemic karst-dwelling species. Thus, these hitherto unprotected fragmented habitats should be given high conservation priority.

We found that two color morphs of *D. buettikoferi* had an identical ND2 haplotype and appeared to be the same species. Some species of *Dopasia*, such as *D. harti* and *D. gracilis*, also have blue markings similar to our male specimens of *D. buettikoferi* (Das 2010). *Dopasia harti* is known to have two color morphs, either with blue dorsal markings or without markings, which does not relate to genetic or geographic groups, but may reflect ontogenetic and sexual variations (Lin et al. 2003). Thus, these morphotypes of *D. buettikoferi* may reflect a sexual dimorphism and variation related to the developmental stage. We also observed the male-male combat of this species. Male-male combat has been reported for other anguine genera, *Anguis* and *Pseudopus* (e.g., Capula et al. 1998; Jablonski 2018). In *Anguis fragilis*, combat outcome tends to favor the larger males (Capula et al. 1998). Such was the case in our observation.

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Supplementary material 1

Male-male combat of *Dopasia buettikoferi*

Author: Takaki Kurita

Data type: MP4 file

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Link: https://doi.org/10.3897/herpetozoa.34.e63998.suppl1

Supplementary material 2

Localities of the specimens

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Data type: Table

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